

Learning about Neutrinos at the First Muon Collider

We assume $E_\mu = 250 \text{ GeV}$. (Neutrino Physics Part I : B. Kayser)

Characteristics of the neutrino beams—

Very high flux, leading to

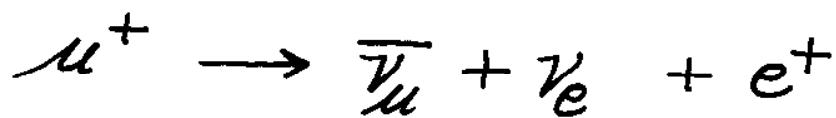
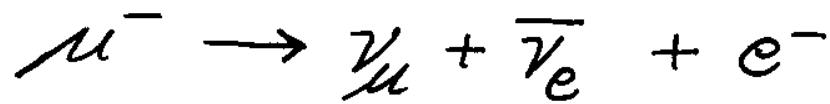
Events/yr $\sim 10^7 \times \text{Detector Length [g/cm}^2\text{]}$.

{If $l_{\text{straight}} = 100 \text{ m}$ } (King)

Variety of energies $\lesssim 100 \text{ GeV}$.

Sharply collimated: $\theta_\nu < \frac{1}{\delta_\mu}$.

Unusual, interesting, precisely-known flavor content:



2) Our focus was on the question:
What neutrino oscillation experiments
can one do with these beams?

What ranges of neutrino mass and
mixing would be interesting to explore.

The current situation was extensively
reviewed —

Theoretical perspective: Mohapatra

Experimental overview
and discussion of MINOS: Goodman
Leeson

K2K : Kobayashi

LSND, mBooNE, BooNE : Stefanski
White
Tayloe

SOME SALIENT FEATURES —

1. The atmospheric neutrino anomaly may be due to

$$\nu_\mu \rightarrow \nu_\tau \quad \text{oscillation}$$

with maximal mixing ($\sin^2 2\theta_{\mu\tau} \approx 1$) and $\Delta m^2 \sim 10^{-(2-3)} \text{ eV}^2$.

New CHOOZ bound on $\overline{\nu}_e \rightarrow \overline{\nu}_x$ makes $\nu_\mu \rightarrow \nu_e$ unlikely.

The confirmation or refutation of the ν oscillation interpretation of the atmospheric anomaly is an important goal of the long-base-line neutrino experiments such as K2K and MINOS.

The low end of the favored Δm^2 range may not be accessible to the first long-base-line experiments.

Recall

$$P(\nu_a \rightarrow \nu_b) \propto \sin^2(1.27 \delta m^2 \frac{L}{E_\nu})$$

The high neutrino flux at the FMC could extend the δm^2 range by making possible a longer baseline L , or increasing the rate at a given L .

But must not defeat the big L by using high-energy neutrinos.

(Goodman)

Peter Fisher will report the ideas presented in the group for exploring the atmospheric neutrino question.

5)
2. Existing bounds on $\nu_e \leftrightarrow \nu_\tau$ are weak

$$\theta_{e\tau} \lesssim 0.14$$

(Mohapatra)

The reason is the absence of a ν_e beam at an accelerator.

The muon collider would remedy this.

Neutrino oscillation experiments
at a muon collider

The ν beams from μ decay will be of a new character:

$$\mu^- \rightarrow \nu_\mu + \bar{\nu}_e + e^-$$

This ν beam contains ν_μ and $\bar{\nu}_e$, but no $\bar{\nu}_\mu$, ν_e , ν_τ , $\bar{\nu}_\tau$.

With lepton charge discrimination one can seek

$$\nu_\mu \rightarrow \nu_e$$

and

$$\bar{\nu}_e \rightarrow \bar{\nu}_\mu$$

via appearance experiments.

ν_τ and $\bar{\nu}_\tau$ appearance experiments are also possible (with sufficient E_ν).

With π^-/π^+ discrimination, one could distinguish between

$$\nu_\mu \rightarrow \nu_\pi^- (\rightarrow \pi^-)$$

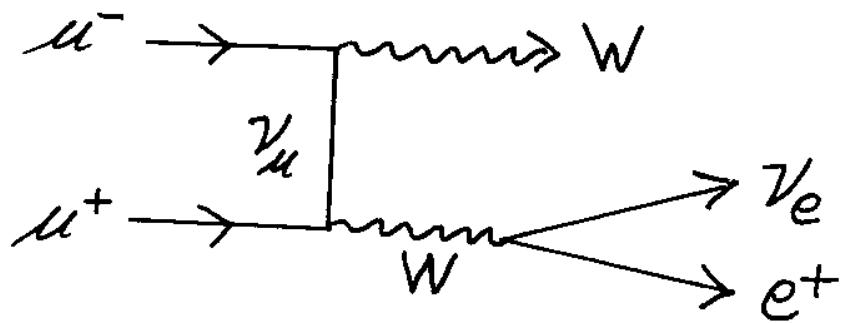
and

$$\bar{\nu}_e \rightarrow \bar{\nu}_\pi^+ (\rightarrow \pi^+).$$

Lepton charge discrimination is important

- Concerns

What about neutrinos produced
in the $\mu^-\mu^+$ collisions?



produces only $\sim 25 \text{ } \nu/\text{yr}$.

(Paschos)

Exotic possibilities

Can we search for $\nu \leftrightarrow \bar{\nu}$?

$$\text{CPT} \Rightarrow P(\nu_\mu \rightarrow \nu_e) = P(\bar{\nu}_e \rightarrow \bar{\nu}_\mu)$$

(Mohapatra)

- Suppose in the neutrino beam from

$$\mu^- \rightarrow \nu_\mu + \bar{\nu}_e + e^-,$$

$\bar{\nu}_\mu$ appears, but is produced by

$$\nu_\mu \rightarrow \bar{\nu}_\mu, \text{ not } \bar{\nu}_e \rightarrow \bar{\nu}_\mu.$$

We may probe whether $\bar{\nu}_\mu$ is from $\bar{\nu}_e \rightarrow \bar{\nu}_\mu$ by seeking ν_e from $\nu_\mu \rightarrow \nu_e$ at a level consistent with

$$P(\nu_\mu \rightarrow \nu_e) = P(\bar{\nu}_e \rightarrow \bar{\nu}_\mu).$$

$\nu_\mu \rightarrow \bar{\nu}_\mu$ may be induced by right-handed currents, or by CPT.

CPT may be introduced via a $\nu^+ \nu$ (not $\bar{\nu} \nu$) mass term, which also violates Lorentz invariance. (Mohapatra)

This leads to

$$P(\nu_\mu \rightarrow \bar{\nu}_\mu) \simeq \sin^2[(\text{Small mass})^2 \frac{L}{E}].$$